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DTC Technology Report

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Quo Vadis? - Providing Real-World Stresses To The Future Combat Systems

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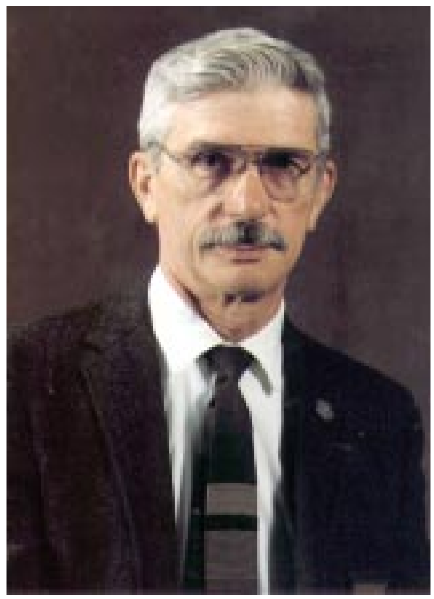
Jim Fasig, Technical Director of the US Army Aberdeen Test Center (ATC), is a recognized leader in the test community. Since his initial assignment as a Fire Control Test Director in 1962, he has been instrumental in establishing Aberdeen Proving Ground as a technology leader in instrumentation, measurement, and analysis of artillery, automotive, and tank weapons. Articles in this edition of the "DTC Technology Report" describe some of the current initiatives Jim is pushing to answer his question "Quo Vadis?" (where are we going?) to support our Future Force.

I have been in the test business for over 40 years and never in that time has the question, "Where are we going; what is the future bringing?" been so important. The Army is going to change drastically and if we, the testers, are not careful, we will be irrelevant. With change, there is clearly opportunity for the bold and imaginative. So, are we up to the test? ATC and all of the Developmental Test Command (DTC) will not only be relevant and up to the test, but will be a key partner in the Army's future. Many opportunities have already arrived on our doorstep, and we have risen to the occasion every time.

"With change, there is clearly opportunity for the bold and imaginative. So, are we up to the test?"



The Stryker Program and the war with Iraq have proven that DTC and the subordinate commands can and do meet any challenge. We cannot, however, rest on our laurels; we must prepare for the Future Force and do it rapidly. The acquisition strategy for Future Combat Systems (FCS) is clearly revolutionary. Every aspect of the Army, including hardware, tactics, and logistics, will change. Military leaders have long dreamed of a battlefield where all systems, weapons, and troops are interconnected. The test community has the pioneering task of assuring not only that each system works, but that it is fully interoperable and functional on the multidimensional battlefield. In the past few years, our focus on developmental testing has been on those details that will ensure that systems pass the operator tests. I assert that our work has to be better than that! We must, as testers, assure that the FCS' part of the Future Force is interoperable and will work successfully during all conditions of combat.

To achieve this goal, we definitely need to develop new tools and rethink how each test center can contribute. Moreover, we must work collectively to stress and analyze the myriad of hardware and software systems essential to the effectiveness of this new force. FCS will depend upon robots, hybrid vehicles, electrochemical weapons, active armor, smart munitions, unmanned aerial vehicles, unmanned ground vehicles, and communications, communications,

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Inside This Issue

TestBytes

"WHO IS WHO IN T&E"

Dr. Ronald Sega

The next several issues of the US Army Developmental Test Command (DTC) Technology Report will provide snapshot biographies for key people that affect test and evaluation (T&E) resources and the Department of Defense (DOD) testing process. From their policy-level positions they make the rules and regulations under which we work, determine the dollars we get, and often the priorities for spending those dollars. We start at the top level with the Honorable Dr. Ronald Sega, DOD's Director, Defense Research and Engineering. He is in continuing contact with the Secretary of Defense on scientific and technical matters and has oversight over the Defense Advanced Research Projects Agency. Dr. Sega supports testing as an essential component of the systems engineering process and the need for transformation of our test ranges. His office is working with the Director of Operational Test and Evaluation to make this happen. His credentials include a doctorate in Electrical Engineering from the University of Colorado, instructor at the US Air Force Academy, assistant professor at University of Colorado, and then dean of their engineering department.

Early in his career he had been an Air Force pilot, with over 4,000 flight hours. In 1990, he joined NASA as an astronaut, and flew as mission specialist on two joint US/Russian space shuttle flights; he was also payload commander for the docking with the space station Mir. He was co-principal investigator for the Wake Shield facility and Director of Operations for the Gagarin Cosmonaut Training Center. He was promoted to the rank of major general in the Air Force Reserves in July 2001 and is currently the reserve assistant to the Chairman of the Joint Chiefs of Staff.

C3 Driver "On Track." A key testing technology program to support the numerous components of the Army's Battle Command System (ABCS) continues to keep step with the Army's changing force structure. A standardized Command, Control, Communications (C3) Driver is being developed under an Integrated Product Team comprised of experts from the Army Test and Evaluation Command; Developmental Test Command; the Operational Test Command; the Program Executive Officer for Command Control, and Communications-tactical; Program Executive Officer for Simulation, Training, and Instrumentation; and the Training and Doctrine Command Analysis Center (TRAC). The driver provides simulation and stimulation; test/exercise planning and control; simulation to C4I linkage; and data collection, aggregation, reduction, analysis, display, and storage for the development, testing, and training of Army C4I systems. Phase 1 of a multi-phased program was completed, with the prototype driver successfully completing ABCS interoperability testing in May 2002. The simulation and stimulation capabilities of the prototype C3 Driver were based upon a "crawl" brigade-level scenario and scenario products (OPORD, time-ordered event list, message threads, etc.) developed by TRAC. In phase 2 (ongoing since May 2002), the C3 Driver is being developed to support multiple blocks of the Army Software Blocking Program, including integration and interoperability certification activities at the Central Test Support Facility at Fort Hood, TX. The C3 Driver is currently supporting the integration of ABCS Version 6.3.6, and ABCS variants of software supporting Operation Enduring Freedom/Operation Iraqi Freedom rotations. In the current and future blocks, C3 Driver will seek to synchronize development activities in order to provide relevant component capabilities to support the ABCS "Good Enough" (Version 6.4), Blue Force Tracker, Joint Tactical Radio System, Warfighter Information Network-Tactical, and Future Combat Systems programs.

Planning Under Way for Test Technology Symposium 2004. Based upon a very successful symposium in 2003 on the subject of distributed testing, a follow-on symposium will be held April 27-29, 2004, in San Diego, California. This symposium will add the training dimension and will also place more emphasis on joint testing. Dr. Sega, Director, Defense Research and Engineering in the Department of Defense, has been invited to be the keynote speaker. Visit the Web site: www.dtc.army.mil for more information.

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Quo Vadis? - Providing Real-World Stresses To The Future Combat Systems

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communications. We have already performed some tests of these items as stand-alone platforms.

Many new programs are interdependent, however, and will come to our testers with great urgency. We must be prepared to respond faster and more efficiently than ever before to assure readiness for combat by the end of this decade!

This edition of the DTC Technology Report provides a sample of ideas and accomplishments ATC has fostered during the past few years, which, hopefully, will stimulate dialogue among our readers. I encourage you to contact authors of the individual articles to share ideas. Three major categories are presented. First, the value of partnerships between Government, industry, and academia. Congressional legislation is imminent that will enable an innovative partnership for test. ATC will lead a pilot "Limited Liability Company (LLC)" for testing. The LLC concept is further described in an article in this report. Second, computer simulations — several new dedicated systems are operational at ATC, and others are being readied. These simulations, such as the "Roadway Simulator," are powerful tools that provide maximum stress to test items without danger to the item or to the operator. ATC's commitment to develop models also gives an insight into the parameters we must measure in "live" tests to build model reliability. Finally, the articles on VISION and anthropomorphic devices cover technical activities essential to future testing and provide a solid foundation on which we shall build.

Embedded instrumentation, smart sensors, technical data warehouses (with precision datamining capability), high-speed imaging, and megahertz data acquisition systems are the tools that provide the backbone of ATC's test capability. Using this arsenal of systems, we shall immerse the FCS' components into an interoperable environment, provide real-world stresses to each item of FCS, make the key measurements, and distribute data promptly to the members of the FCS acquisition team. Application of the ATC test technology during the early development phases will assure interoperability by validating the capability of each system component.

To assure that the DTC testers are relevant in fielding of the Future Force will require the best effort by each test center and a fully integrated approach to testing. By a continuing quest for testing excellence, we support our motto to "test for the best" and provide our fighting men and women with the edge essential for victory.

Mr. Fasig welcomes your comments. Please contact him at 410-306-4001, or email at james.fasig@atc.army.mil.

ATC Pilot Program For The Limited Liability Company

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The concept of partnership and technology transfer between Government agencies and industry has existed for many years. The transfer of technology has had some success, but true partnerships for testing have yet to be realized. One of the three categories of technology emphasized by the US Army Aberdeen Test Center (ATC) Technical Director is that of partnering with industry and academia. ATC expects to facilitate this partnership via a Limited Liability Company (LLC) as described herein.

Selection of ATC. The Department of Defense (DOD) was directed by the Defense Authorization Act (DAA) in 1999 to select one laboratory and one test & evaluation (T&E) center from each Service to serve as pilot commands. Their mission was to enhance partnerships and technology transfer between academia and industry; waive regulations that impede efficiency; recommend changes to laws that impede mission; and in general get more "bang" for each research, development, test, and evaluation dollar spent. ATC's request to be considered for selection as the pilot command for the Army was approved by DOD. ATC proceeded to establish a group that would conceptually match the intent of the legislation to study alternatives, concepts, and methods to enhance T&E for DOD. ATC selected Cooperative Research and Development Agreement partners and two business consultants to develop an implementation strategy for the study. The initial concept involved creating a T&E company with industry and academia that would meet the letter and spirit of the law. This was briefed to the Director, Operational Test and Evaluation (OT&E), who funded ATC with $150,000 to study the concept.

Emergence of the LLC. Research into a wide variety of partnering and contracting methods as well as various corporate structures was conducted. During this study ATC was placed under a new major command, the Army Test and Evaluation Command. As a steady stream of feedback led to improvement in the concept, the group would meet for discussion with the aid of legal counsel from all participants. Concepts developed were then passed through a series of feasibility filters to determine

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ATC Pilot Program For The Limited Liability Company

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optimum options. The best options had to meet the letter and spirit of the law, fully support Army goals, maintain command direction, appeal to potential nongovernmental partners, and be a more efficient way of doing T&E. The result was the formation of an LLC, with members coming from academia, business, and ATC. Benefits included significant cost avoidance, reinvestment in infrastructure, simple corporate structure, economic incentives for all partners, and liability protection for partners. This concept also met the directive to create a fresh approach to doing business in nontraditional ways, while not creating a new business process. While legislation would still be needed to achieve the desired result, the merits and estimated gains were felt to merit the effort. As the command channels and various Pentagon agencies were briefed about the LLC idea, ATC continually received favorable response and encouragement to advance the concept. The concept was advanced to the staff of the Senate Armed Services Committee and the House Armed Services Committee. Staff representatives of both committees approved the concept, provided that a precedent be shown for the idea and that the legislation go through appropriate channels.

Draft Legislation. The final pilot concept adopted by ATC was the formation of an LLC. This was again briefed up the chain of command with universal acceptance up through the DOD Director of OT&E. However, legislation is required to enable the formation of the LLC. A draft of this legislation was prepared and staffed through the chain of command. At the same time the Army Business Initiatives Council passed this concept as one of their initiatives and the Secretary of the Army directed that enabling legislation be pursued. The Director of the Test and Evaluation Management Agency is the champion of this effort and required legislation is expected to be in place by Fiscal Year 2005.

Selecting Partners. ATC plans to advertise a Sources Sought Synopsis to gain one or more industrial and one or more academic partners and form this company. An impartial selection committee will be established to select the partners. This selection will be based on their technical capabilities, abilities to attract new business, and synergies they would present to ATC and potential partners in the T&E business. Each partner will contribute $150,000 for start-up and operating costs. A pro forma budget has been created, based on revenue of $450,000 (the minimum estimated startup capital). If more partners are brought into the company or revenue streams from workflow in to the LLC, additional funds will exist. A board of members will direct policy for the company. Each partner will be represented on the board by the ATC Commander or the Technical Director as chairperson. This is similar to the Family Housing initiatives used by the US Army today. A small salaried staff would conduct operations, marketing, and administration. They will be augmented by contracted legal, accounting, and other essential service providers. People with additional skills will be hired by contract for specific projects, with LLC partners having the right of first refusal for the work.

LLC concept avoids competition with the core business of any partners

Concept of Operation. The LLC concept of operation prevents the company from competing with the core business of any partner. For example, program managers will continue to come to ATC for developmental testing. It would make little sense for them to go through the company and pay its overhead for these services. However, for full scientific resolution of problems and for specific tests for other Government agencies, industry, or to support research grant work, this company is ideal. A request for quote would come to the company from a potential client. The company would then request quotes from each partner that might participate on the job. Partner quotes would be compiled, appropriately burdened, and submitted to the requester. If the requester selects the company to do the job, the company would issue work orders to participating partners who would perform the work and be paid. Final work product would be that of the LLC. The board of members would direct division of funds annually. ATC would be permitted to use its share of funds for essential infrastructure investments. This is part of the needed legislation so that funds can be retained at the local command. Since this is an LLC, tax issues pass from the company to each partner. Matters relating to national security at ATC would always have priority. Partners who wish to join the LLC will agree to this statement and the operating agreement so that they are clear on this issue from the beginning.

A Winning Situation. LLC will provide a winning situation for all players. An increased workload coming to ATC will positively impact direct labor, reduce overhead, and optimize the use of all facilities. Benefits also include reduced acquisition leadtime, cross-fertilization of talent, and funds to reinvest into infrastructures. Industrial and academic partners will see similar benefits, including access to ranges and sophisticated instrumentation. Congress will regularly review performance and conduct corporate audits to gauge success. DOD will have the same data, and at the end of this experiment decide whether to export the concept throughout the testing community. Since the experiment is small, the risk is small, especially when considering that core business is not impacted and only the monetary investment in the company is at risk.

For more information, please contact John Roth at 410-278-0537, or email at jack.roth@atc.army.mil.

Versatile Information Systems Integrated ONline (VISION) - An Overview

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US Army Aberdeen Test Center

The crown jewel of the US Army Aberdeen Test Center (ATC) testing methodology is the Versatile Information Systems Integrated ONline (VISION) program. It employs a web-centric approach that merges and exploits the most advanced instrumentation and information management technologies. Its use is being adopted across the US Army Test and Evaluation Command and is being specified in the test plans for Future Combat Systems.

Background. In the 1970's, ATC developed and deployed the Automatic Data Acquisition and Processing Techniques (ADAPT) System. ADAPT was completely successful in its capabilities to acquire data, process the data at the test site, and provide results to data customers. One desirable feature identified during ADAPT's requirements discovery – a data repository – was never implemented, however. The necessary tools, such as a relational database technology and the Structured Query Language, had not yet been developed, and networking was in its infancy. ADAPT grew and evolved over time, serving our data collection and processing needs for well over 20 years, but never evolved to the point of incorporating the data repository. In the mid-1990's, the need for a top-to-bottom information architecture overhaul became evident. Architecture redesign addressed the following features:

- Instrumentation with capabilities to meet existing and emerging test needs;
- Data would be accompanied by the requisite metadata (data on surrounding conditions; e.g., weather, test item identification);
- A bi-directional data link to mobile instrumentation for information download as well as command and control;
- A data repository compatible with sophisticated test instrumentation would be central to the deployed system; and
- Information would be easily available to qualified users for primary use and reuse.

VISION Triad. The product of compiling these features was a VISION triad consisting of the three elements as shown in figure 1. Accomplishments are as follows:

- Development of hardware and software architectures;
- Development of a family of modular instruments referred to as Advanced Distributed Modular Acquisition System (ADMAS);
- Establishment of an IEEE 802.11b wireless network infrastructure which provides network connectivity to mobile test items throughout ATC test areas;
- Development of a data repository; and
- Development of a data warehouse infrastructure and the VISION digital library.

The VISION major instrumentation program is in the second of 5 years. While VISION products are in daily use, there is much work to be done. Smart sensor development is in its infancy. The data warehouse concept needs to evolve and mature. Infrastructure-less Mobile Ad-hoc NETwork (MANET) technologies are being investigated to support tests where no infrastructure is possible. Additional instrumentation types and more compact, less power-hungry implementations are required.

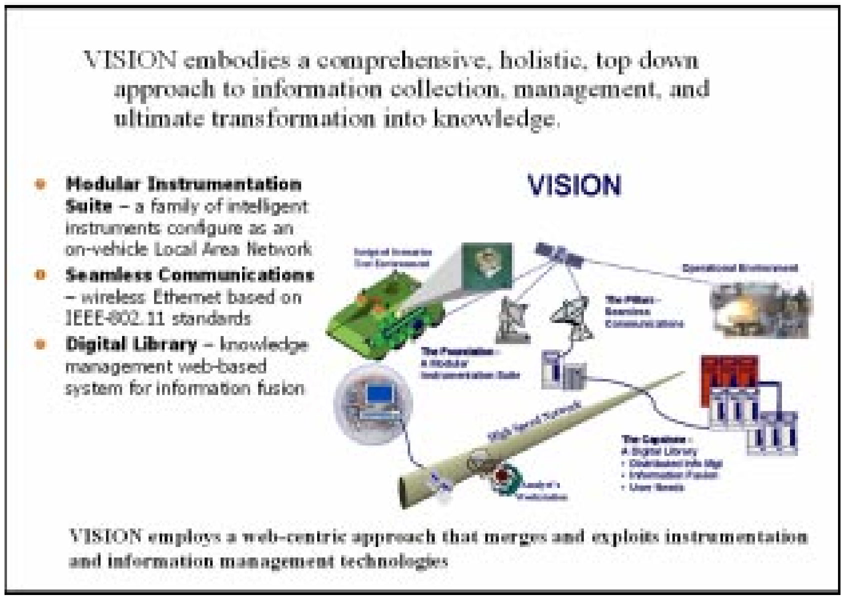

Figure 1. The VISION End State

The Modular Instrumentation Suite Element. In order to be used in operational scenarios, instrumentation systems must be compatible with the operational environment. Instrumentation systems must operate autonomously or be operated remotely. Instrumentation systems must be small and unobtrusive. Large, monolithic instrumentation devices are not acceptable. Measurement capability must be rapidly reconfigurable to accommodate a large variety of vehicles and weapon systems. Instrumentation systems must provide their own power or consume little of the vehicle's power. Instrumentation systems must not interfere with vehicle operations in any manner. A major goal of VISION is to establish open instrumentation hardware

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Versatile Information Systems Integrated ONline (VISION) - An Overview

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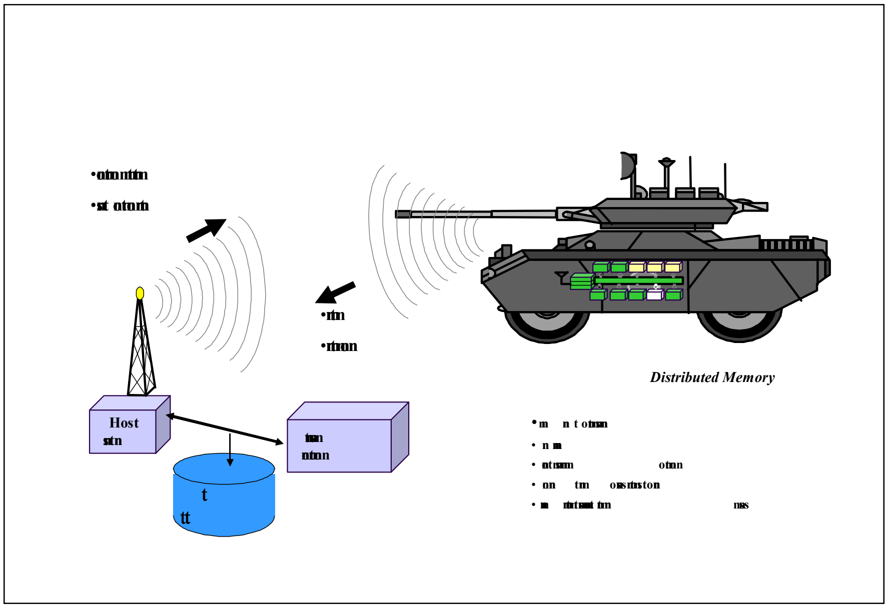

Figure 2. VISION In Use

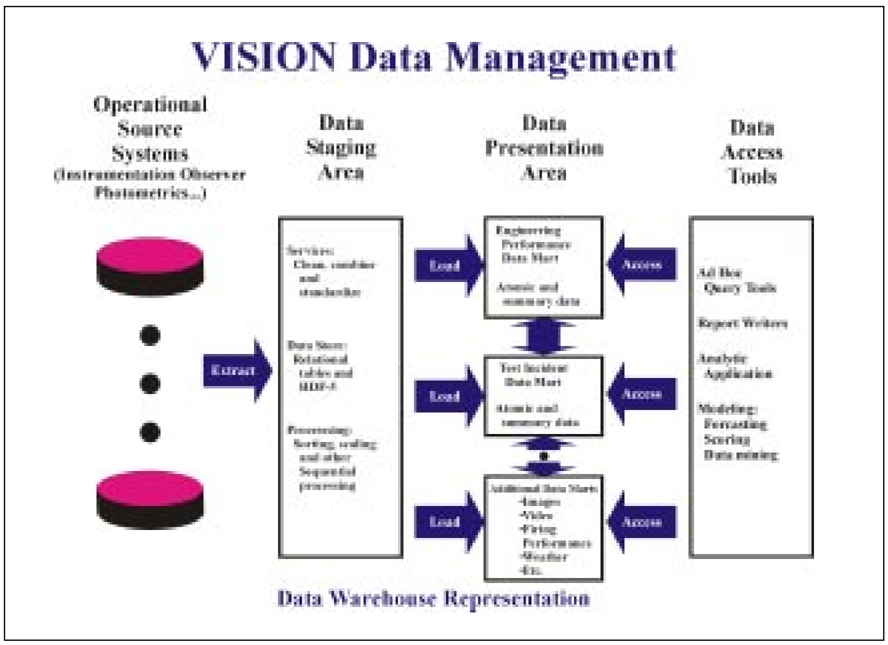

Figure 3. VISION Data Management

and software architectures to achieve interoperability among various major test and training instrumentation subsystems and to enable the instrumentation repertoire to be easily added to as needs increase. VISION instrumentation can be thought of as networked Internet appliances, where VISION communication establishes wireless/ mobile Internet connectivity at the test item level. By implementing a network centric architecture, based on established standards, seamless information flow from instrumentation all the way to enterprise information management resources can be assured.

Figure 2 depicts a typical instrumentation setup. Note the on-vehicle instrumentation network, the bi-directional data link, and the host system with applications distributed through Java Web Start.

The Seamless Communications/ Data Management Element. At ATC a "tower farm" has been installed whereby network connectivity is assured to mobile test platforms throughout the campus. Standard commercial-off-the-shelf IEEE 802.11b products are used. We are currently developing MANET infrastructure-less capability for use at off-campus sites. VISION's primary concern is not merely data collection, but rather focuses on the ultimate fate of data, its use in the synthesis of information and knowledge, how it is archived, and how it is used in modeling & simulation. Within VISION, metadata collection begins before test data collection.

The Digital Library Element. Figure 3 shows VISION's overall data management concept. This depiction is done in terms of a classic data warehouse. This concept allows data from different sources to be loaded into distinct databases (Data Presentation Area), but as long as each database conforms to a common set of metadata, data can be extracted and combined.

The VISION Digital Library provides the Data Access Tool functionality, but in addition enables comprehensive document management, collaboration, work flow management, online scoring, and other features.

VISION Accomplished. The "vision" which began in the '70's has become a reality. This versatile, integrated, online system stands ready to meet the extensive test requirements of our Future Combat Systems.

For additional information, please contact Dr. Sam Harley at 410-278-9463, email: samuel.harley@atc.army.mil.

ATC Support Of Intelligent Vehicle Initiative

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The US Army Aberdeen Test Center (ATC) recently concluded a Department of Transportation (DOT) program titled the Intelligent Vehicle Initiative (IVI). The goal of the IVI program was to increase safety on the Nation's highways through the acceleration of the deployment of on-vehicle safety devices. Working through a cooperative research agreement with Volvo Trucks North America (VTNA), ATC's Versatile Information Systems Integrated, ONline (VISION) Team and Automotive Instrumentation Team provided data acquisition and archiving services. The 3-year, 100-vehicle nationwide field operational test allowed DOT, VTNA, their evaluator (Battelle), and a commercial fleet, US Xpress, to understand the required technical performance, user acceptance, and benefits of the collision countermeasures.

Background. Through previous research, the National Highway Transportation Safety Administration was able to develop initial estimates which show that rear end, lane change, and roadway departure crash avoidance systems have the potential, collectively, to reduce motor vehicle crashes by one sixth, or about 1.1 million crashes annually. Such systems may take the form of warning drivers, recommending control actions, and introducing temporary or partial automated control of the vehicle in hazardous situations. US DOT harnessed these efforts into one program, the IVI. The VTNA portion of the commercial vehicle (figure 1) study emphasized the adaptive cruise control, rear end collision warning, and implementation of electronic braking systems. Electronic braking systems are being fielded for the first time in the United States.

Figure 1. Volvo Class-8 Commercial Truck

ATC Data Acquisition System (DAS). The VISION Team is continually developing data acquisition systems to meet US Army test requirements, since commercial-off-the-shelf equipment does not always meet the requirements. The most recent effort, part of the VISION program, has improved on past systems by implementing information management and network models, in addition to hardware upgrades. The Advanced Distributed Modular Acquisition System (ADMAS) is composed of multiple devices which are small and rugged. The DAS for the IVI project was a modification of an ADMAS device. The DAS hardware consisted

Figure 2. IVI Data Acquisition System (DAS)

of a PC/104 form factor computer with data acquisition and communications interfaces. The computer utilized a real-time operating system and stored the application program and data in solid state media. The system included a cellular modem, 220-Mbyte flash memory card, and an Uninterruptible Power Supply in a rugged aluminum enclosure (figure 2).

IVI Application. The IVI program began in June 2000 and ended in September 2003. The DAS units were installed during truck manufacturing along with associated wiring harness that interfaced to the vehicular data buses. The data bus interfaces were the Society of Automotive Engineering (SAE) J1939, SAE J1708, and the Collision Warning System (CWS) data bus. The DAS had a 16-channel analog input, but for IVI only three channels are used. The longitudinal and lateral accelerations were measured by accelerometers integrated with the DAS package. The third analog input was a string potentiometer situated to measure steering wheel position. The Global Positioning System (GPS) information was acquired by monitoring and recording the serial data from a GPS receiver. This source provided time and position data for every data file recorded.

The DAS software was a variant of the ADMAS software and was tailored for the IVI performance specifications. The DAS software worked with a configuration file. The configuration file described which parameters to record, how to record the data, settings for parameter limits, realtime algorithm performed on the data, and many other options. The specifications required that specific parameters from three vehicle data buses be monitored and recorded along with analog sensor inputs and GPS receiver parameters. In the IVI application, we recorded data in three formats: histogram, triggered time history, and time-tagged events. Histograms provided a statistical summary of vehicle activity over a period of time, when factors such as vehicle speed, brake applications, and cruise control use were considered. The triggered time history files were generated when a parameter exceeded a specified limit. The circular data buffer was an area in memory that temporarily stored a specified amount of data. If specified

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ATC Support Of Intelligent Vehicle Initiative

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limits were exceeded, then a trigger event was created. When the trigger event occured, the previous 10 seconds of data were stored permanently along with the values at the trigger time and 5 seconds of data after the trigger event. This format was used to store data when the data set described a potentially hazardous situation. Time-tagged events were single snapshots of a specific set of parameters on occurrence of an event. This format was used to record information when any of the warning system alerts were provided to the driver.

Data files were then compressed and stored in solid state media until they were sent through the cellular modem. Each DAS attempted to call in its data files to ATC when the host vehicle was stationary and there was a good cellular signal. Data files received correctly were deleted from the DAS. Data received were automatically loaded to a database. Final archiving and databasing of the data occurred at the Major Shared Resource Center at the Army Research Laboratory, Aberdeen Proving Ground, MD.

The database interface used a graphical user interface accessible through a Web browser. A combination of java server pages, servlets, and applications was developed to aid the user in accessing the required data in report or download format. Because the chosen database structure was one of the industry leaders, there existed many third party tools available to aid in the manipulation of the data. Some of the identified requirements were composite histograms, histogram comparisons from similar events, and time history comparisons from similar events.

For additional information, contact Gino Mastrippolito at 410-278-7736, email: luigi.mastrippolito@atc.army.mil.

ATC's Roadway Simulator - Up And Running

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Another step towards support for the Army Future Force was taken on April 16, 2003. On that date, a formal ribbon-cutting ceremony opened the world's largest Flat-Trac® simulator. The new "hardware in the loop" simulator will be a key asset for testing advanced mobility vehicles and their associated technologies. Greg Schultz, a US Army Aberdeen Test Center (ATC) engineer since 1988, is the individual who has spent the last couple of years getting the new facility "up and running."

A New Tool in the Toolbox. ATC, long the recognized leader in testing tanks, trucks, and trailers, now has an advanced vehicle dynamics and power-train test machine in their "toolbox." This new tool will greatly enhance the test and evaluation of wheeled vehicles. Identified as the Roadway Simulator (RWS), it provides an efficient new approach for performance and durability testing. Bringing the simulator to operational status was accomplished in three phases. Phase 1 provided the capability to test two-axle wheeled vehicles with gross vehicle weights up to 11,800 kg (26,000 lbs). With phase 2, the capability was extended to accommodate three-axle vehicles (tandem-axle trucks) with gross weights up to 27,240 kg (60,000 lbs). Phase 3 will

Figure 1. Roadway Simulator

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ATC's Roadway Simulator - Up And Running

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extend the capability to tractor-trailer combinations with gross weights to 36,320 kg (80,000 lbs).

The RWS is based on Flat-Trac® technology (MTS Systems Corp.) and was designed for a wide variety of performance, safety, and durability tests on light to heavy military and commercial trucks. The total facility is in a highly instrumented, well-controlled safe environment that is unaffected by undesirable weather conditions. It enables extension of engineering analysis and test parameters, and provides highly repeatable measurements. There are five major components: (1) a series of Flat-Trac® units positioned beneath the vehicle tires; (2) an instrumented vehicle restraint system; (3) an autopilot; (4) a hydraulic power supply; and (5) a system controller.

Ultra-Realism Achieved With Hardware-in-the-Loop Methodology

The Flat-Trac® units allow the vehicle to drive and provide vertical excitation. They can also be steered to allow vehicle cornering. The restraint system constrains the test item about its center of gravity in the longitudinal, lateral, and yaw directions, while allowing the vehicle to move naturally in the vertical, pitch, and roll directions. The restraint system also provides vertical aerodynamic loading, if desired. The autopilot operates the vehicle steering wheel, throttle, brake, clutch, and shifter based on commands generated in the user interface. Both manual and automatic transmissions are supported.

RWS Operation. The simulator can be operated in two control modes, "road load" and "road speed." The principle of operation in road-load control is based on Newton's second law of motion, F = ma. The simulator reacts kinematically to forces exerted by the truck; in other words, the truck drives the simulator. Conversely, during road speed control, the simulator drives the truck. Road speed and road load control can also be applied with vertical motion capability to conduct vibration and ride quality tests. Light trucks, including sport utility vehicles, can be driven up to 193 km/hr (120 mph) on the simulator, while heavier trucks can be tested up to 113 km/hr (70 mph). The simulator is capable of producing enough power to do a sustained maximum effort brake stop on heavier trucks from 100 km/hr (62 mph) to zero speed.

Benefits. Use of the RWS will provide vehicle developers and testers significant benefits grouped into three categories: safety, engineering, and cost savings.

Significant benefits in safety, engineering, and cost savings

At the top of the priority list for test of any vehicle is safety. Under battle conditions, soldiers may need to push the vehicle's envelope of performance, often beyond the levels prescribed by operating manuals. To properly evaluate safety, testers must do the same. On outdoor test tracks, testing trucks to their limits of stability is inherently dangerous, even when the trucks are equipped with outriggers. The danger increases when testing is conducted at high speeds. A major payback for the RWS is elimination of this hazard to the operator.

A second test objective is to obtain enough high-quality data to assess performance and durability. Testing in the RWS laboratory provides a distinct advantage in the amount and quality of engineering data compared to that available from outdoor test tracks. The laboratory is a "sensor-rich" environment. Force is measured for each tire contact patch in five degrees of freedom. The restraint system measures forces at the center of gravity of the vehicle longitudinally and laterally, as well as the yaw moment. It also measures vertical displacement, roll motion, and pitch motion. This depth of data enables quick quantitative comparisons between vehicles when design changes are made.

Of course, developers are always alert to ways of reducing costs. Test costs and vehicle development costs can be reduced through the use of RWS technology. Information can be acquired earlier in the vehicle development, and overall vehicle development time can be reduced through greatly compressed testing schedules. A reduced vehicle development cycle yields reductions in direct costs to the program, as well as reductions in soft costs such as the opportunity cost of a delayed product introduction.

Summary. The new Roadway Simulator is an important new technology for ATC's Automotive Core. It complements ATC's "open air" test courses and offers an excellent source of data for design and qualification of automotive components of the Army's Future Combat Systems. The facility will provide the Department of Defense, Department of Transportation, Department of Energy, state agencies, automotive and truck manufacturers, commercial trucking, and technology-oriented colleges with standardized automotive testing. It is a key asset for testing advanced-mobility vehicles and associated technologies required by Army transformation.

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"Calibrating the Dummies" Anthropomorphic Test Devices Must Be Realistic

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A well-known shortfall in the simulation of weapon (and other) systems is the inability to adequately represent the human operator. This component of the system is probably the most vulnerable and contributes greatly in the overall performance of the system. This article discusses an area of technology that targets the human simulation problem and how crash dummies are calibrated for impact test and simulation.

Introduction. The US Army Aberdeen Test Center (ATC) is the leading developmental testing agency possessing the capability of measuring human injury parameters in many types of military vehicles. ATC uses Anthropomorphic Test Devices (ATD's) to simulate human occupants and to generate measurable physical parameters to external stimuli. ATC possesses two classes of ATD's, the Hybrid II ATD and the Hybrid III ATD. The Hybrid II is an older design which exhibits a lesser degree of biofidelity than the Hybrid III. Both types possess the capability to measure three axes of acceleration in the head, chest, and pelvis locations. Hybrid III ATD's also possess the capability to measure forces and moments in the neck, lumbar spine, femur, knee, and tibia locations. Of the Hybrid III ATD class, ATC currently owns three types: the 5th, 50th, and 95th percentile; the percentiles refer to the size of the ATD's. The Hybrid III 50th percentile ATD represents an average US male (approximately 172-lb), the 95th percentile represents a larger male, and the 5th percentile represents a small female.

Calibration Laboratory. ATC operates an ATD Calibration Laboratory (ATDCL). This facility possesses the capability to perform six different calibration tests on an ATD. These tests include a Head Drop, Neck Flexion, Neck Extension, Thorax Impact, Knee Slider, and a Knee Impact procedure. These calibration tests were originally developed by the Society of Automotive Engineers for automotive crash testing. Prior to testing, ATC calibrates each ATD as a system, to ensure that it is operating properly and is ready for any testing environment to which it will be subjected.

Head Drop. The Head Drop Calibration procedure involves dropping an ATD head approximately 14 inches on to a steel plate, as shown in figure 1. Prior to impact, an optical sensor initiates a data acquisition cycle that records the acceleration of the head during its collision with the table. The resultant acceleration is then computed from the digital tri-axial acceleration data. If the calculated resultant acceleration is within acceptable limits for the ATD class and type, then the head is passed. If the resultant falls outside the acceptable limits, adjustments to the head are made, and the head is retested. This process continues until the resultant acceleration falls within the acceptable limits.

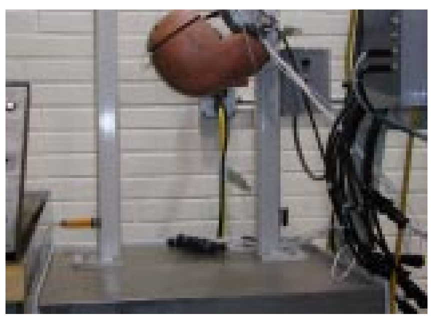

Figure 1. Head Drop Test

The Neck Extension and Neck Flexion calibrations (figures 3 and 4) are the methods used to verify proper neck response of Hybrid III ATD's. Both of these procedures address neck shear forces, as well as head and neck rotation about the shoulders. As shown in figure 2, the head and neck assembly is mounted at the end of a pendulum arm. After raising the pendulum arm to the desired orientation from the impact position (neck flexion: 120 degrees, neck extension: 90 degrees), the pendulum is released for impact.

The pendulum arm contains a small aluminum bracket on its impact side. As the pendulum falls, it will come in contact with a piece of aluminum honeycomb that will slow the pendulum down. Just prior to impact, the pendulum's aluminum bracket will pass by a fiber optic sensor. This sensor will start a data acquisition cycle that will record data throughout the collision. The data are immediately analyzed by software that calculates pendulum deceleration, neck lateral moment, and rotation about the end of the pendulum. If the lateral moment and shear forces recorded are within a given range, the head and neck assembly is passed. The passable ranges are

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Figure 2. Impact Position

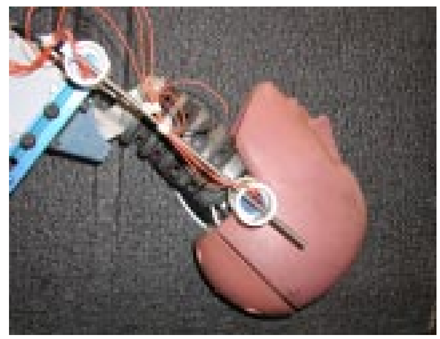

Figure 3. Neck Extension Setup

Figure 4. Neck Flexion Setup

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different for each Hybrid III type.

Thorax Impact Calibration. The Hybrid III ATD also possesses the ability to measure the deflection of the chest from frontal impacts. The Thorax Impact calibration test requires the ATD to be resting on an adjustable platform, as shown in figure 5. A 23.18 KG pound cylindrical aluminum probe with an attached accelerometer is raised 229 centimeters above the 3rd rib of the ATD. The probe is then released, and swings past a fiber optic sensor and impacts the ATD chest in line with the 3rd rib. The fiber optic sensor initiates a data acquisition cycle, and data are recorded throughout the impact. An analytical routine is initiated which calculates probe velocity and sternum deflection. If the probe velocity is between 6.5 and 6.83 m/s and sternum deflection is calculated between 64 and 73 mm, then the ATD passes.

Knee Impact Calibration. The Knee Impact and Knee Slider calibration procedures are procedures that may be conducted for calibrating a knee load cell if the knee activity is required to be measured during a test. These procedures are quite similar to the thorax impact test in that they use variable weighted probes with accelerometers. These smaller probes swing on cables and strike the ATD knee. Fiber optic sensors are used for the triggering data acquisition cycles that record the data throughout impact.

Figure 5. Thorax Impact

The data generated are used to compare actual probe decelerations and impact forces with acceptable levels. As with all of the calibration procedures, if the actual levels fall outside of acceptable boundaries, then those parts of the ATD are adjusted and retested until the ATD component tests in the acceptable range.

Summary. The ATDCL calibration procedures have proven to be invaluable for developmental tests that require crew response measurements. All ATD responses are verified prior to placing each ATD into a test vehicle. Upon completion of the test, each ATD is returned to the ATDCL for post calibration and examination. An ATDCL database was developed to catalog all calibration information to include ATD specifications, ATD usage, and any discrepancies or anomalies as indicated by the test data.

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ATC's Warfighter Training Capability Supports Joint Force Combat Readiness

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Emphasis continues to grow across the Department of Defense to test and train as we fight. This requires integrated joint testing of systems of systems. Measurement and data processing technologies available within the test communities are being applied to training exercises which help assure joint force combat readiness. The Warfighter Core at the US Army Aberdeen Test Center (ATC) has been assisting in joint training exercises over the past 7 years.

ATC is known worldwide as a center of excellence for testing military technologies. In 1996, a significant ATC command decision was made to expand their regular testing capabilities to enable support of Joint Warfighter training. Since that time, ATC has been supporting various training missions, and is establishing its place as a part of the training process. During June 1999 and July 2000, two significant Joint Training Exercises were conducted at Aberdeen. These were the first major exercises attempted. They were known as Exercise "Blue Crab" and consisted of combined land, sea, and air task forces with 1,200 personnel from 37 active duty, Reserve, and National Guard units. Army, Navy, Air Force, Marine Corps, and Coast Guard all had units participating in the exercises.

The exercises demonstrated ATC's capability to support the warfighter within the full spectrum of warfighter disciplines. Although these exercises were very successful, they required a large part of ATC's resources, impacting other testing, and it was determined that Aberdeen was not an ideal location for continuing large-scale force-on-force operations. Nonetheless, as a result of its experience with the Blue Crab and other training exercises, ATC continues to support training. It is currently focusing on the special operations warfighter.

Following this refocus to support special operations forces training, in April 2001 ATC began a relationship with the US Naval Special Warfare Command (SPECWARCOM), (Groups Two and Four) located at the Naval Amphibious Base at Little Creek, Virginia. This

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Figure 1. Rigid Hull Inflatable Boat

partnership has proven extremely beneficial to both ATC and SPECWARCOM, as training has been conducted almost on a continuous basis since that time.

ATC's location at the top of the Chesapeake Bay provides a unique capability to Special Operations Warfighter training units. With its restricted water areas surrounding live-fire ranges and restricted airspace, training units are able to conduct complete mission scenarios in a realistic real-world environment. Special Boat Teams and Navy SEAL Teams from SPECWARCOM have conducted a variety of joint live-fire mission scenarios at ATC during the past two years. Some of these missions included live close-air support with Air Force A-10 Thunderbolts and AC 130U Specter Gunships, as well as numerous rotary-wing aircraft. Exercises included hot extractions and insertions, live-fire Boat Team exercises with 11-meter Rigid Hull Inflatable Boats (see figure 1), and the Mk V Special Operations Craft, and live-fire ground assault missions. All of these training exercises have been highly successful, and were conducted with little or no interference with the ATC testing mission. Support of training, including "joint forces" exercises, is now a part of the ATC mission and is expected to expand to meet Joint Forces combat readiness needs.

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